Implications of Measured Commercial Building Loads on Geothermal System Sizing

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Overview

- Purpose & Objectives
  - quantify loads and load diversity in Geothermal applications
- Describe test sites, data collection, and analysis methods
- Compare measured loads from each site
- Implications for geothermal loop sizing

Objectives

- Analyze measured heating and cooling load data from several commercial buildings to:
  - determine peak loads and load diversity
  - determine full load cooling and heating hours
- Compare load characteristics of various building applications
- Show the implications of measured loads on geothermal loop sizing

Monitored Buildings

Sun Prairie, WI Office Building

Middleton, WI Office Building

Geneva, NY Hotel

Johnson City, TN High School

Buildings Characteristics

	Sun Prairie Office Building	Middleton Office Building	Geneva Hotel	Johnson City High School
Building				
Building Description:	two-story office	seven-story office	149 room hotel	high school
Building Size:	27,000 ft^2	76,000 ft^2 (86% w/ WLHPs)	100,000 ft^2	161,600 ft^2
Installed Capacity:	69 tons	146 tons	284 tons	400 tons
Floor Area per ton:	391 ft^2/ton	448 ft^2/ton	352 ft^2/ton	400 ft^2/ton
Construction Date	1990	1990	1997	1995 (renovation)
Heat Pumps				
No. of Heat Pumps:	30	54	198	118
Average EER (ARI 320)	11.4 Btu/Wh	11.4 Btu/h	14.8 Btu/Wh	14.5 Btu/Wh
Loop Pumps				
Number and Size:	(2) 5 HP pumps	(2) 15 HP pumps	(3) 50 HP pumps	(2) 40 HP pumps
Flow Rate:	200 gpm (2.9 gpm/ton)	475 gpm (3.3 gpm/ton)	810 gpm (2.5 gpm/ton)	1,200 gpm (3 gpm/ton)
Norm. Pump Power	0.072 HP/ton	0.010 HP/ton	0.31 HP/ton	0.20 hp/ton
Pump Control	Constant Speed	Constant Speed	Variable Speed	Dual Two-Speed (staged: ½, 1, 2)
Ground Loop				
Ground Loop	na	na	198 pilings, 85 ft deep (33,660 ft) 120 bores, 138 ft deep (33,120 ft)	320 Bores, 150 ft deep (96,000 ft)
Norm. Loop Size	na	na	103 ft of bore/ton	120 ft of bore/ton
Cooling Tower				
Type	fluid cooler	fluid cooler	na	na
Cooling Fan:	20 HP fan, 2-speed	20 HP fan, 2-speed	na	na
Design Capacity:	1.0 million Btu/h	1.4 million Btu/h	na	na
Boiler				
Input	500,000 Btu/h	962,000 Btu/h	na	na

Monitored Data Collected

- Hotel (NY)
  - measured loop heat rejection/extraction… flow-delta-T (5-min data)
- Offices (WI)
  - measured total HP power (kWh) & loop temperatures (15-min data)
- High School (TN)
  - measured loop heat rejection/extraction… flow delta-T (60-min data)
  - measured heating/cooling status of each heat pump

Office Methodology

- Used measured loop loading & assumed COPs to calculate heating and cooling loads

$$Q_{cooling} = [measured\_kW] \cdot COP_c(T)$$

$$Q_{heating} = [measured\_kW] \cdot COP_h(T)$$

where: $COP_{c,h}(T)$ = HP efficiency as a function of loop supply temperature T

Hotel Methodology

- Used measured loop loading & assumed COPs to calculate heating and cooling loads

$$Q_{cooling} = Q_{rejection} \cdot \frac{COP_c(T)}{COP_c(T)+1}$$

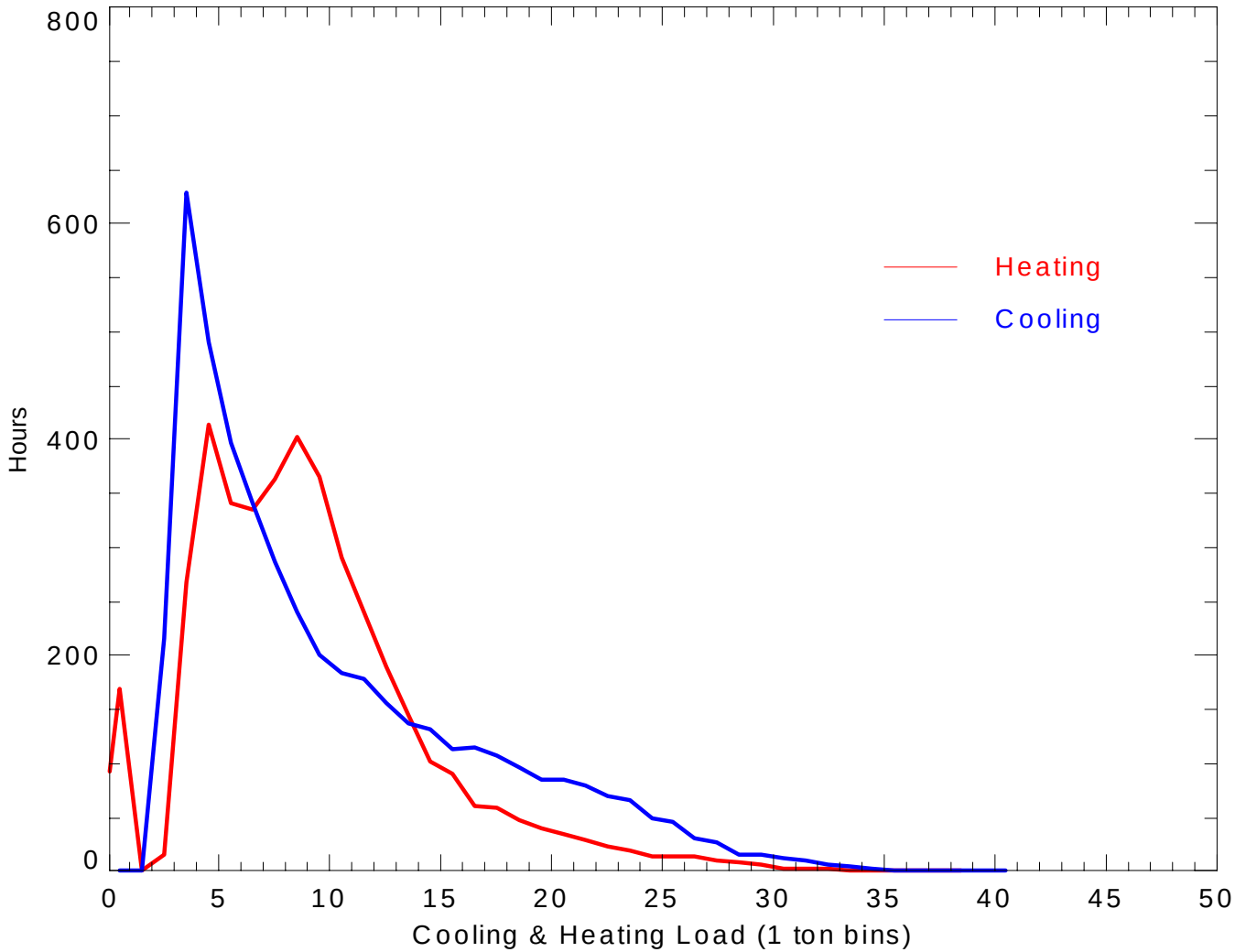
$$Q_{heating} = Q_{extraction} \cdot \frac{COP_h(T)}{COP_h(T)-1}$$

where: $COP_{c,h}(T)$ = HP efficiency as a function of loop supply temperature T

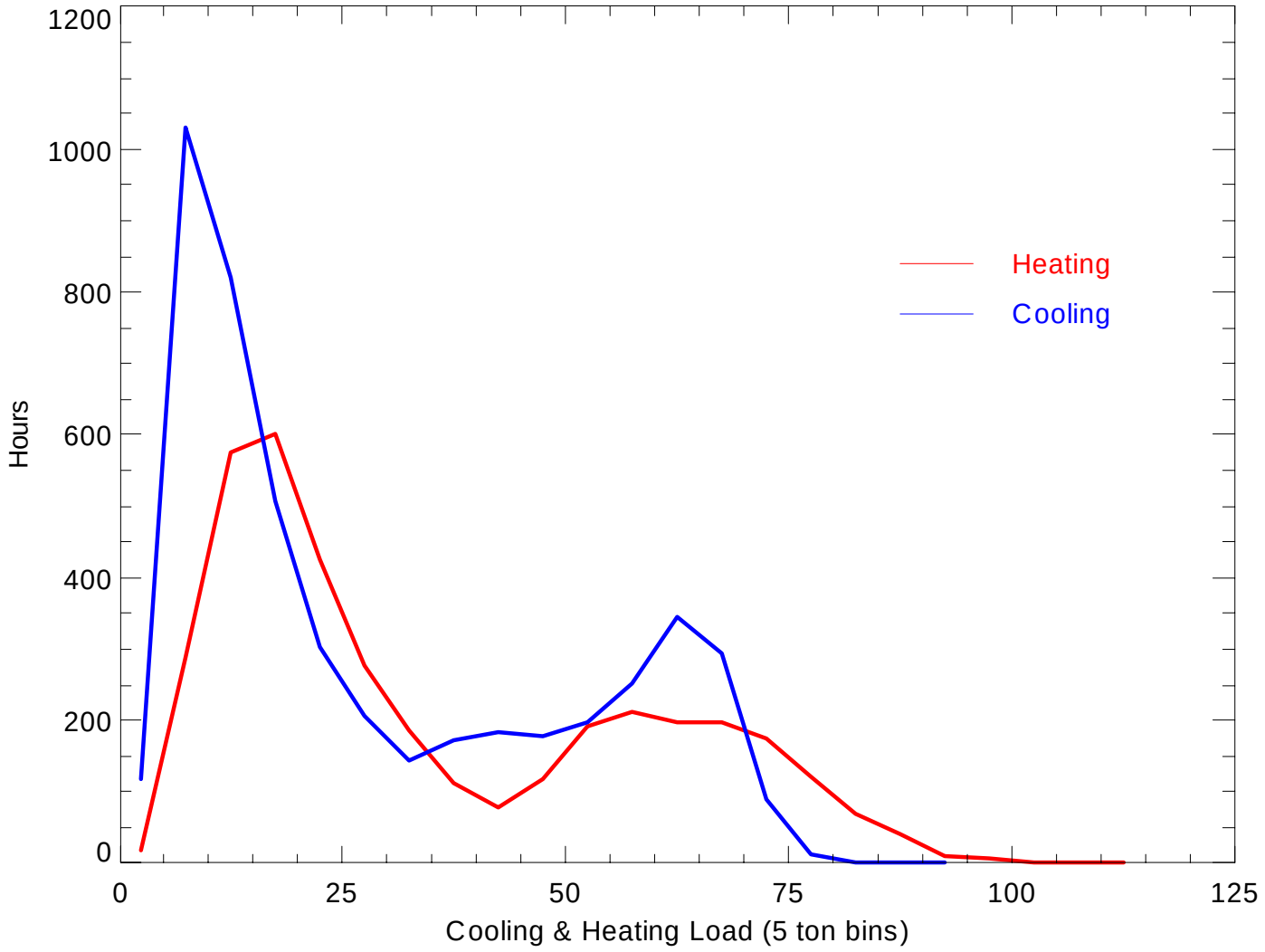
School Methodology

- Used heating/cooling status data with known HP sizes
- Adjusted HP capacity data based on loop temperatures i.e., CAP(T)
- Also calculated (and measured) loop loading

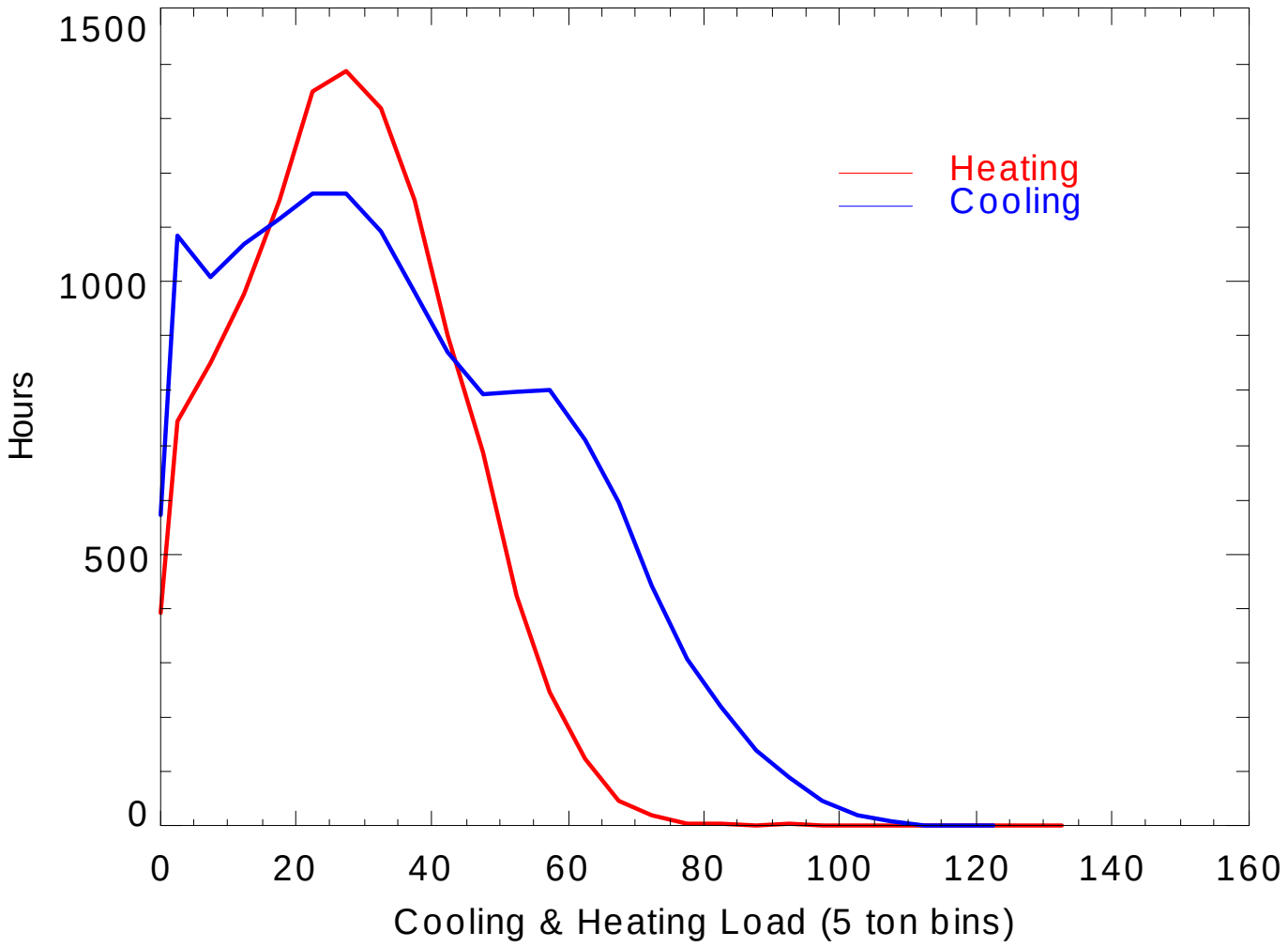
Sun Prairie Office (69 tons)



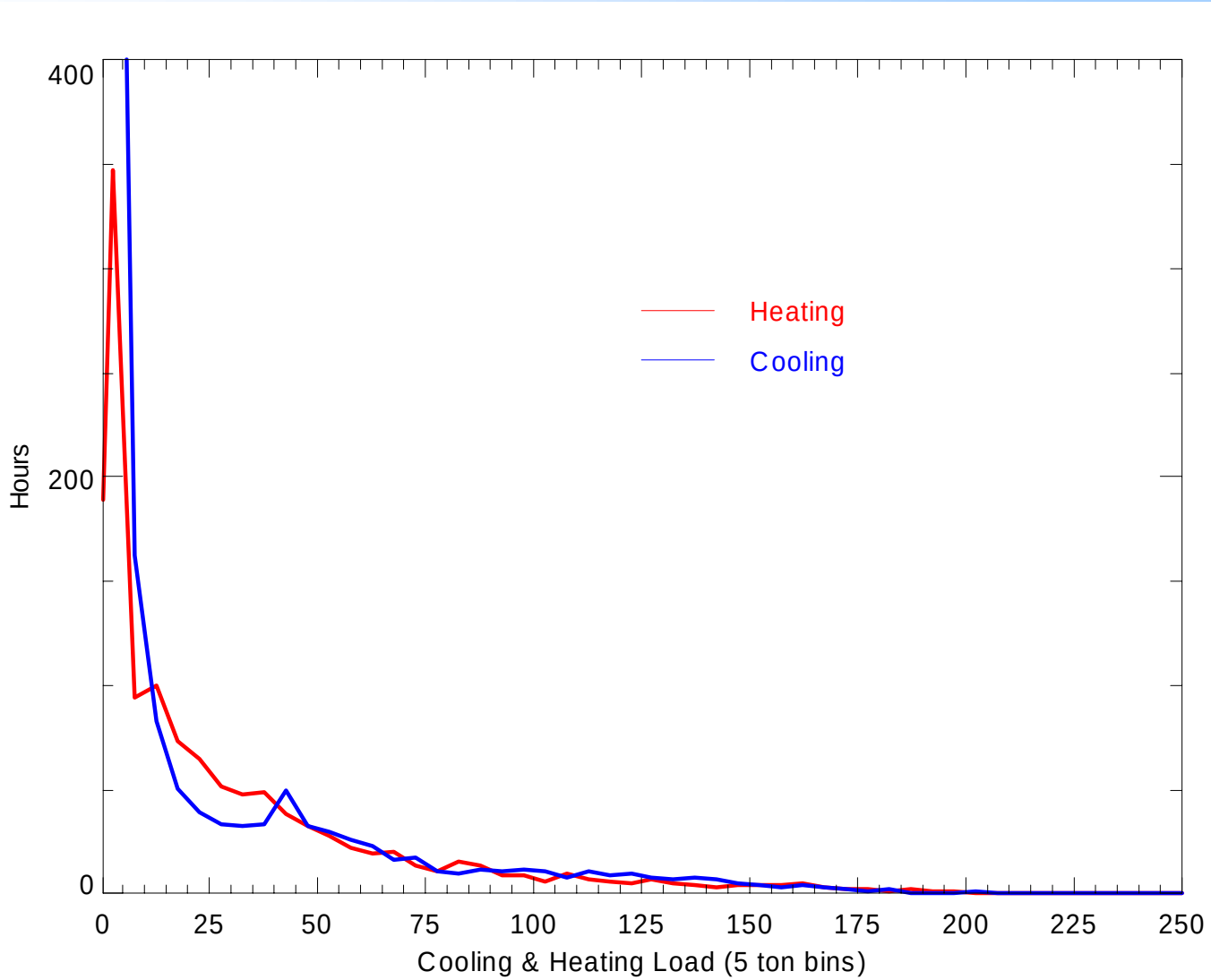
Middleton Office (146 tons)



Geneva Hotel (284 tons)



Johnson City School (400 tons)



Cooling Load Diversity

Hours at or Above Each Loading Level - Cooling

Percent of Installed COOLING Capacity	Sun Prairie Office	Middleton Office	Geneva Hotel	High School
0%	4,635	4,857	4,840	6,566
5%	4,137	4,348	3,841	2,007
10%	2,595	2,943	2,767	1,446
15%	1,768	2,230	1,795	894
20%	1,201	1,899	1,032	619
25%	781	1,674	393	441
30%	462	1,413	101	285
35%	215	1,147	12	152
40%	79	833	-	74
45%	25	350	-	28
50%	2	30	-	17
55%	-	1	-	4
60%	-	-	-	1

Heating Load Diversity

Hours at or Above Each Loading Level - Heating

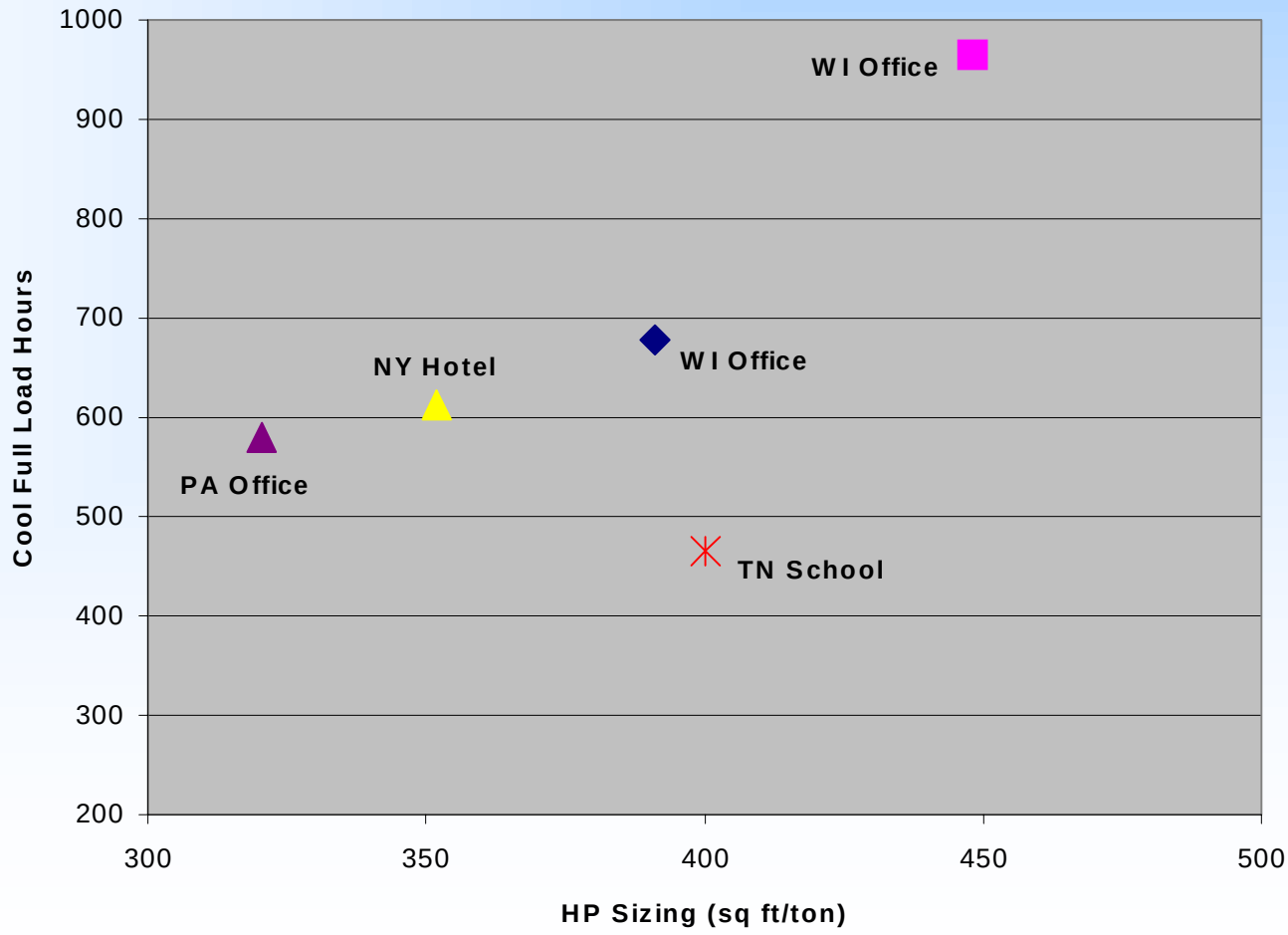
Percent of Installed HEATING Capacity	Sun Prairie Office	Middleton Office	Geneva Hotel	High School
0%	3,957	3,903	3,804	4,596
5%	3,779	3,751	3,001	2,384
10%	2,418	2,906	1,799	1,599
15%	1,106	2,093	664	1,054
20%	489	1,649	119	745
25%	240	1,432	14	545
30%	114	1,291	5	388
35%	50	1,014	2	288
40%	12	689	-	208
45%	2	382	-	148
50%	-	150	-	92
55%	-	39	-	51
60%	-	9	-	28
65%	-	1	-	-

Heating/Cooling Load Summary

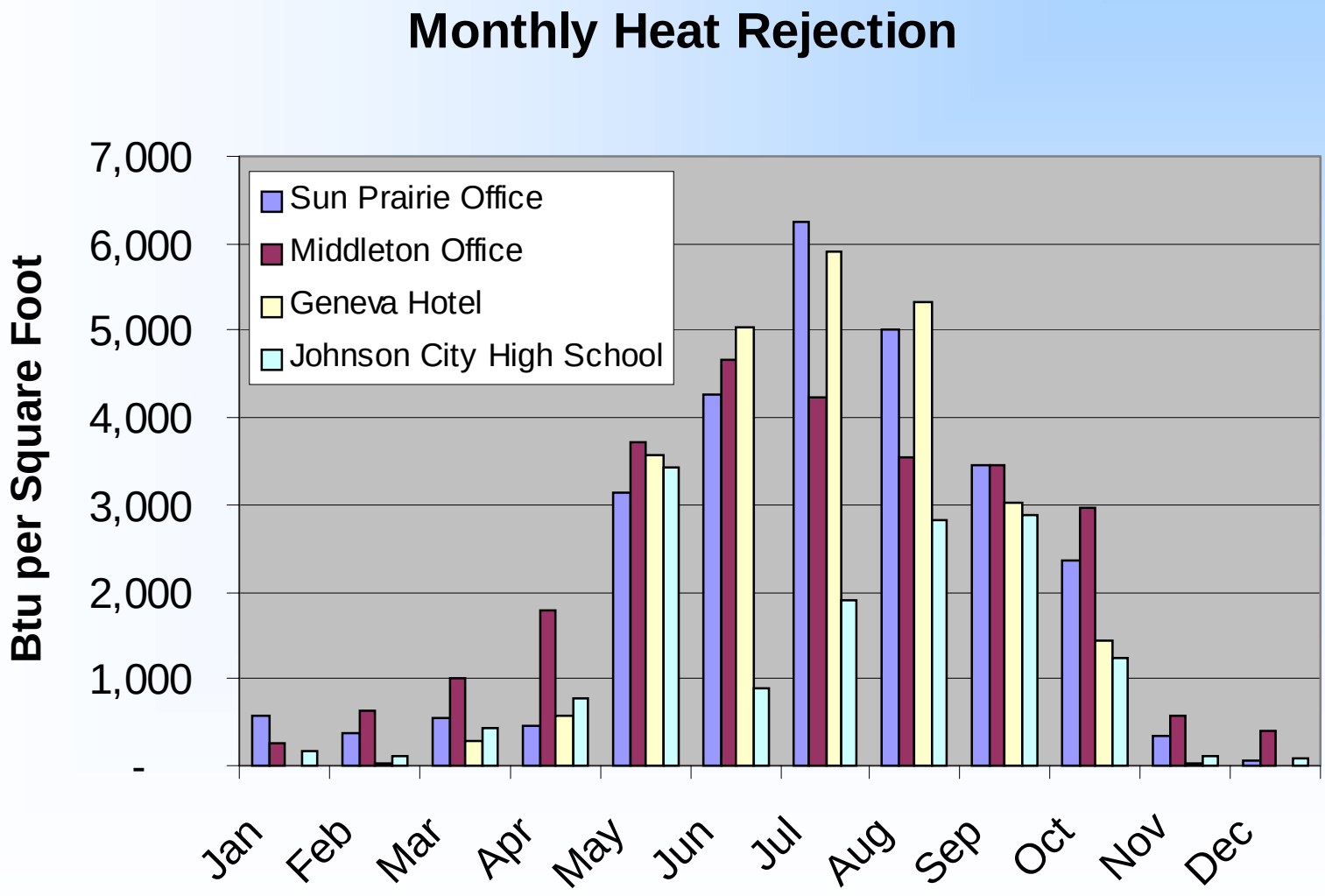
	Sun Prairie Office	Middleton Office	Geneva Hotel	Johnson City High School
Peak Hourly / 4-hr Cooling Loads:	34 / 32 tons	82 / 74 tons	106 / 101 tons	234 / 219 tons
% of Installed Cooling Capacity	49% / 47%	57% / 50%	37% / 35%	58% / 55%
Equivalent Full Load Hours – Cooling	679 hours	965 hours	613 hours	466 hours
Equivalent Full Load Hours – Heating	504 hours	869 hours	372 hours	318 hours
Normalized Cooling Loads	1.7 ton-h/ft^2-yr	2.2 ton-h/ft^2-yr	1.7 ton-h/ft^2-yr	1.2 ton-h/ft^2-yr

Are Full Load Hours the Right "Rule of Thumb" ?

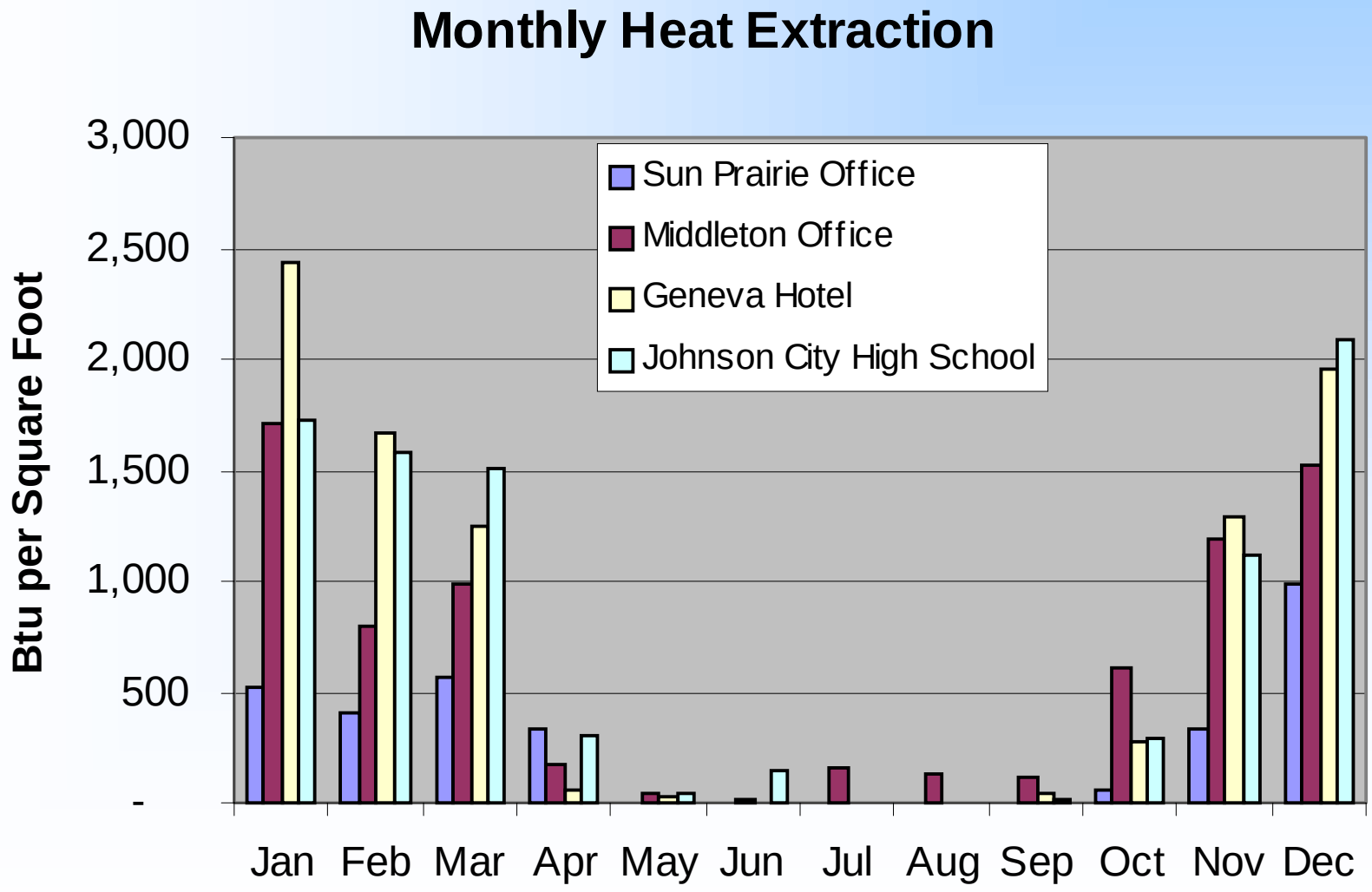
- Full load hours (FLH) depend on sizing
- Norm. cooling loads are more consistent



Heat Rejection - All Sites



Heat Extraction - All Sites

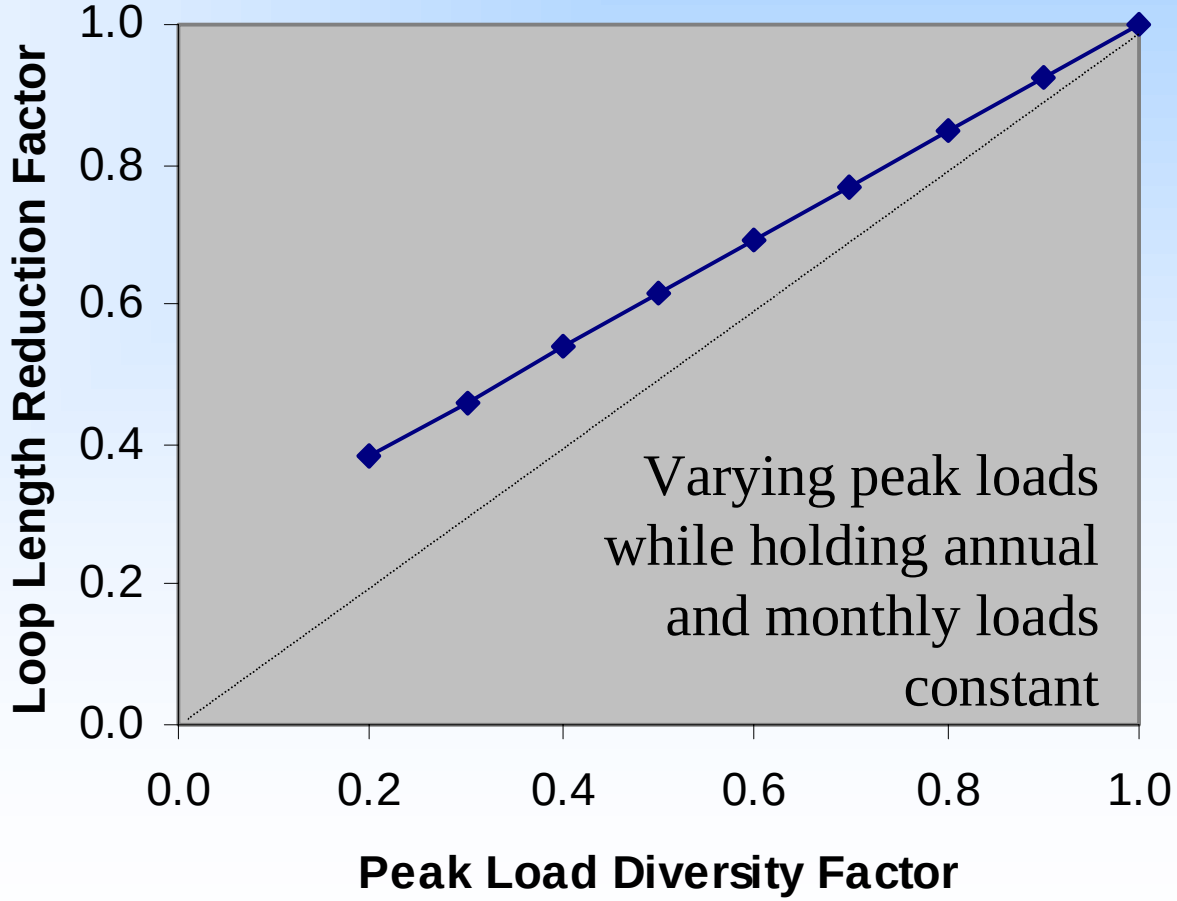


Loop Load Summary

	Sun Prairie Office	Middleton Office	Geneva Hotel	Johnson City High School
Peak Hourly / 4-hr Heat Rejection (Btu/h-ft^2)	22.2 / 20.5	42.5 / 29.9	15.6 / 14.8	22.5 / 20.6
Peak Hourly / 4-hr Heat Extraction (Btu/h-ft^2)	6.2 / 4.7	23.4 / 12.2	8.7 / 7.1	13.3 / 11.1
Normalized Annual Heat Rejection (MBtu/yr-ft^2)	26.8	27.3	25.2	14.8
Normalized Annual Heat Extraction (MBtu/yr-ft^2)	3.3	7.5	8.9	8.8

Implications of Load Diversity on Ground Loop Sizing

- ASHRAE loop sizing procedure shows loop length is mostly a function of peak loads



Summary of Findings

- Peak cooling loads were 40 to 60% of installed capacity…high diversity
- Loads found to be similar for diverse mix of buildings… schools being the exception
- Cooling full load hours (FLH) ranged from 466 to 965…though but may not be the best rule of thumb
- Load diversity has significant implications on loop sizing…using 50% diversity factor would allow 40% reduction in loop size